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CHARACTERIZATION OF *OREOCHROMIS NILOTICUS* STRAINS OF YALELO FISHERY OF ZAMBIA USING MORPHOMETRIC METHODS

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ABSTRACT

Oreochromis niloticus fish was collected from Yalelo Fishery in May, 2020. A Dendrogram was used to delineate the sampled specimens using PC-ORD™ Software and the differences among strains were tested using One-way ANOVA in Statistix 9 Software (P = 0.05). Morphometric analysis showed that the sampled fish could be characterized into eight different strains. These results showed that the tested fish samples could be grouped into 8 types based on morphometric characters. The morphometric differences among the sampled O. *niloticus* strains may have appeared due to genetic differences among the collected specimens.

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INTRODUCTION

The Nile *Tilapia*, *Oreochromis niloticus* (Linnaeus, 1758) (Cichlidae; Teleostei), is a widespread species used in tropical aquaculture. Natural populations of these fish occur in Africa and the species O. *niloticus* has been introduced to almost every tropical country in the world for aquaculture purposes (Nchimunya *et al*., 2018).The Fisheries sub-sector in Zambia contributes approximately 3.2% to the National Gross Domestic Product (GDP). The Aquaculture sub-sector currently contributes 27% of the total fish produced in Zambia. The sector has experienced some increase in production from 12, 998 metric tonnes in 2012 to 32, 888 metric tonnes in 2017. Aquaculture production is expected to increase by 1, 148 metric tonnes by December, 2020 due to the various interventions by the Zambian Government (Zambia Daily Mail, 2020). The increase in fish production is attributed to the commercialization of the Fisheries sub-sector which has witnessed an increase in the number of people venturing into fish farming. Fish exports amounted to US$503, 649 in 2015 (Nchimunya *et al*., 2018) and by December, 2020 fish exports are targeted to soar upto US5.0 million (ZAEDP, 2019).

Besides the economic returns from *Tilapia* Aquaculture, tilapiines have also been adopted for use as control-agents for aquatic vegetation and elimination of unwanted aquatic fauna such as snails and mosquitoes (Bradbeer *et al*., 2018).

Oreochromis niloticus is the most widely cultured bream in Zambia and its success in Lake Kariba Culture Fisheries is because it is extremely hardy, it has a wide range of trophic and ecological adaptations, and it possesses adaptive life history characteristics such as fast growth, high fecundity, big egg sizes that have few predators, high dietary overlap across size, class, habitat and season (Nyingi *et al*., 2009; Zengeya *et al*., 2012; Nyirenda, 2017). 'Characterization' refers to the description of a character or quality of an individual or entity (Merriam-Webster, 1991). The word 'characterize' is synonymous to the word 'distinguish', that is, to mark as separate or different, or to separate into kinds, classes or categories.This identification may in broad terms refer to any difference in the appearance or make-up of an accession. The term 'characterization' refers to the description of characters that are usually highly heritable, easily seen by the eye and equally expressed in all environments (Siankuku, 2016).

Morphometric and the meristic methods remains the simplest and most direct way among methods of species identification. From previous studies (Katongo, 2005; Yakubu and Okunsebor, 2011; Chuhila, 2015; Samaradivankara *et al*., 2012), it is understood that the analysis of phenotypic variation in morphometric characters or meristic counts is the method most commonly used to delineate stocks of fish. Despite the advent of techniques which directly examines biochemical or molecular genetic variation, these conventional methods continues to have an important role in stock identification even to date (Bradbeer *et al*., 2018). The general objective of the study was to characterize *Oreochromis niloticus* strains of Yalelo Fishery using morphological and meristic methods. The study used simple and cheap methods to establish whether or not the O. *niloticus* fish species being reared at Yalelo Fishery were the same or not. It is important to characterize the cultured fish species in order to re-strategize management practices and adopt species-specific management tools. It is hoped that the results of this study will form the basis of taxonomic description of O. *niloticus* strains of Yalelo Fishery.

MATERIALS AND METHODS

The study was conducted from Lake Kariba (Figure 1) which lies between latitude 16º28'S and 18º06' S, and longitude 26°40'E to 29º03' E. Lake Kariba has a catchment area of 663,000km^2 with a maximum length and maximum width of 280km and 40km. Lake Kariba has a total surface area of 5,580km^2. Lake Kariba has a water storage capacity of 185 km^3, making it the largest man-made lake in Southern Africa (Yalelo, 2012). Fish samples were collected from cage Aquaculture fish farms of Yalelo Fishery. The research was conducted from Lake Kariba because it houses Zambia's largest Commercial Fishery called Yalelo Fishery Limited, and it is the largest man-made Lake in Zambia that has diverse ecological habitats that are rich in fish biodiversity. Yalelo Fishery Limited is a commercial Fishery which is located inKamimbi bay along longitude 28.63°E and latitude -16.47°S.Yalelo Fishery has a maximum production capacity of 10, 000 metric tonnes per year. 66 fish samples were collected from Yalelo Fishery Limited.

A total of 23 morphological characters were used for this study. 22 morphometric measurements were conducted on each fish species using Vernier callipers, dividers and fish measuring boards while weight was measured using an SF-400A electronic scale.

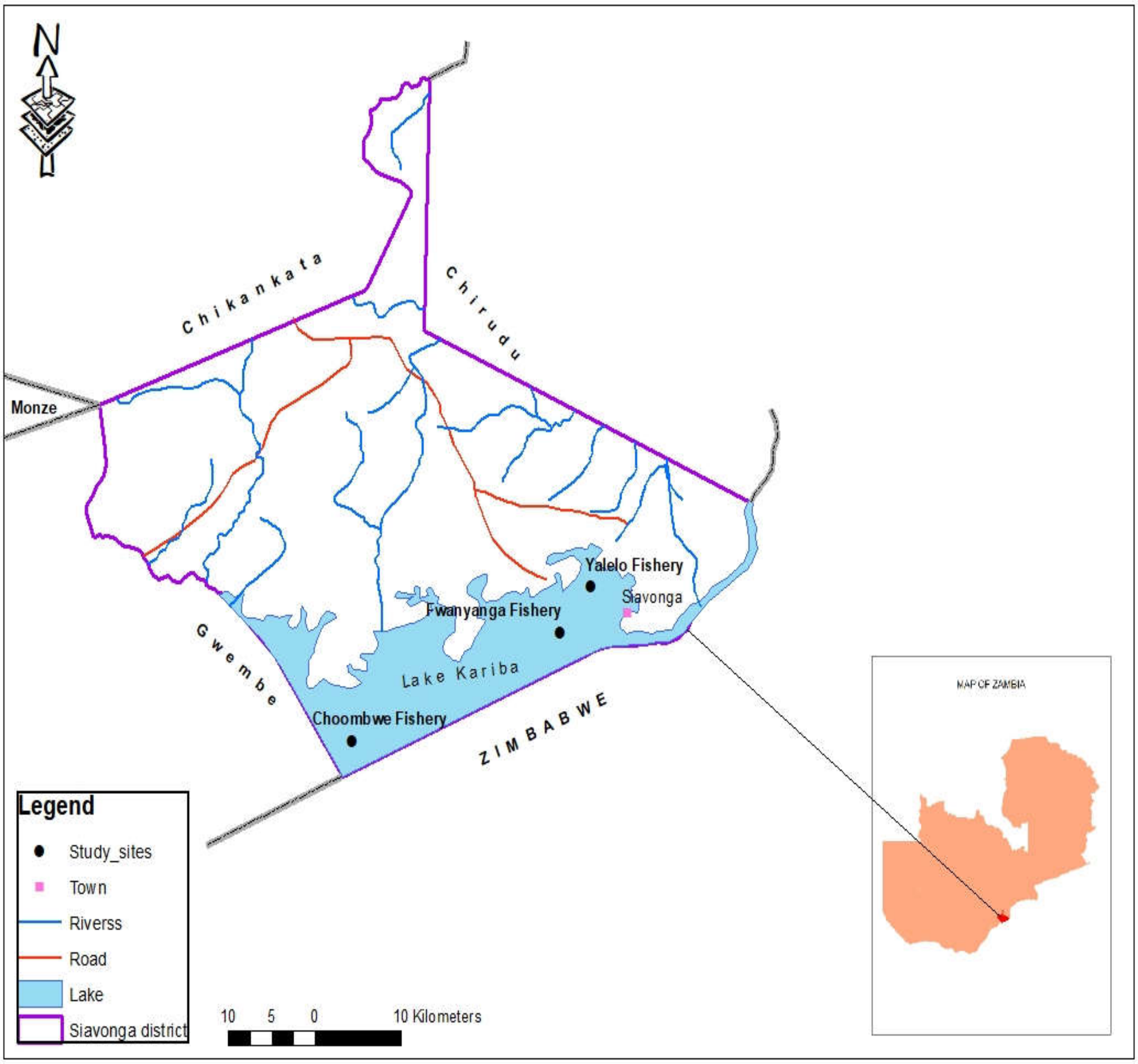

Figure 1. Location of Yalelo Fishery within Lake Kariba

The 22 morphometric measurements were measured to the nearest 0.1cm while body weight was measured to the nearest 0.1g.Morphometric measurements included (Figure 2) total length (TL), standard length (SL), head depth (HD), body height (BH), head length (HL), pre-dorsal distance (PDD), pre-anal distance (PAD), pre-pectoral distance (PPD), pre-ventral distance (PVD), pectoral fin length (PFL), ventral fin length (VFL), dorsal fin base length (DFBL), anal fin length (AFL), inter-orbital distance (IOD), eye diameter (ED), snout length (SNL), caudal peduncle length (CPL), Caudal peduncle depth (CPD), greatest dorsal spine length (GDSL), third anal spine length (TASL), longest anal ray length (LARL) and post-orbital length (POL).

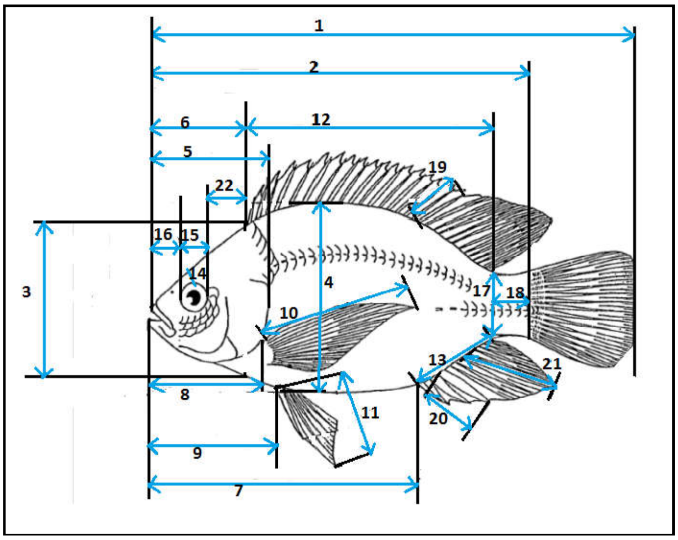

Figure 2. Diagram of morphometric measurements (Adopted from Vreven *et al*., 1998)

To avoid possible biases produced by size effects on the morphometric variables, all morphometric characters were standardized in PC-CORD™ Software version 5.10 (McCune and Melford, 2006) before dendrogram construction.Statistix Software version 9.0 (Analytical Software, 2009) was used to determine significant differences (P = 0.05), if any, among the morphometric variates of the identified strains. IBM Statistics Software version 21.0 (SPSS, 2012) was used in multivariate analysis by determining the number of principal components and in communalities test to find the most important morphometric measurement that was important in the characterization of the sampled fish species.

The growth exponent coefficient (b) was determined by linear regression from the length-weight relationship (LWR) in Microsoft Excell, 2016 (Analytical Software, 2016) using the equation by Pauly, (1993): $W = aL^b$

where W = weight in grams, L = total length in centimeters, a is a scaling constant and b the growth exponent coefficient. This equation was logarithmically-transformed and expressed as: log Weight = a + b log Total length.

RESULTS

The dendrogram that was constructed to characterize the collected *Oreochromis* fishsamples of Yalelo Fishery Limited based on morphometric measurements is given in Figure 3. The dendrogram in Figure 3 showed that morphometrically, the sampled fish specimens of Yalelo Fishery can be characterized into 8 different strains (types) at 50% similarity index.One-way Analysis of Variance (ANOVA) conducted on the morphometric using Statistix Software version 9.0 (Analytical Software, 2009variates of identified strains showed that there were significant differences (P = 0.0000) among the morphometric variates of the 8 *Oreochromis niloticus* strains at Yalelo Fishery. Although the ANOVA results showed significant differences among the strains, the Least Significant Difference could not be performed because all morphometric variates had a standard error of almost 1.0.

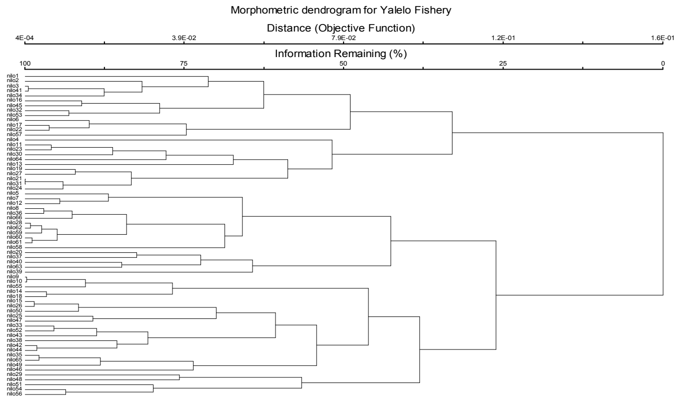

Figure 3. Dendrogram of morphometric measurements of sampled fish from Yalelo Fishery

The identified strains were discriminated on 6 principal components. The smallest eigen value was 1.018 in principal component 6 and the largest eigen value was 9.728 in principal component 1. Other eigen values were 1.182 (principal component 5), 1.237 (principal component 4), 1.488 (principal component 3) and 1.833 (principal component 2). The extracted 6 principal components accounted for a total of 71.028%. The contribution of each morphometric measurement to the observed variation in each of the 6 principal components is given in Table 1.

Table 1. Principal components, eigen values, percent variance and cumulative percent Variance of morphometric variates of Yalelo Fishery

Principal Component number	Eigen value	Percent variance	Cumulative percent variance
1	9.728	42.295	42.295
2	1.833	7.468	49.763
3	1.488	6.468	56.231
4	1.237	5.379	61.61
5	1.182	5.138	66.748
6	1.018	4.28	71.028

The communalities test that was conducted using IBM Statistics Software version 21.0 (SPSS, 2012) in order to find out the overall influence of the 23 morphometric characters to the observed variations and hence determine the most important character in the description of *Oreochromis niloticus* strains of Yalelo Fishery showed that total length with an extraction coefficient of 0.903 contributed the most to the observed variations.The variations among the identified strains are given in Table 2.

DISCUSSION

The general sentiment shared by Fisheries managers regarding Lake Kariba Culture Fisheries is that there are many different strains of *Oreochromis niloticus* being farmed by Aquaculture farmers (Nasilele, 2020). Morphometric results of this study showed that there are 8 strains of *Oreochromis niloticus* being farmed at Yalelo Fishery. These morphometric results are in agreement with other studies by Chuhila (2015) who morphometrically identified two species of *Oreochromis*

Table 2. Growth exponent coefficients and associated statistical results of identified strains

Strain number	AverageTL (cm)	Average BW (g)	r	r^2	b	p	Comment
1	24.6	289.0	0.578	0.112	2.5	0.308	*
2	23.2	250.0	0.303	0.0161	0.757	0.301	**
3	23.1	246.2	0.884	0.708	1.85	0.0467	*
4	23.1	237.5	0.451	-0.0619	2.38	0.446	**
5	22.5	211.0	0.488	0.162	1.071	0.107	**
6	21.8	204.0	0.649	0.358	1.75	0.0306	*
7	20.3	157.0	0.951	0.855	2.34	0.0495	*
8	21.3	181.0	0.505	0.148	0.799	0.166	**

Key: TL means Total length, BW means body weight, r is the Pearson's correlation coefficient, r^2 is the coefficient of determination, b is the growth exponent coefficient, p is the probability (determined at 5%), * means significant while ** means not significant.

niloticus at Lake Barigo. Vreven *et al*., (1998), and Yakubu and Okunsebor (2011) also identified two specie of *Oreochromis niloticus* using morphometric analyses. Samaradivankara *et al*., (2012) also delineated *Tilapia* samples from Reservoirs in Sri Lanka into four groups using morphological methods. The results of the study agree with Rafael *et al*., (2018) hypothesis that most fish farmers keep more than one *Tilapia* strain and there is a possibility of the presence of interstrain hybrids. Morphometrically, the characters measured in all principal components except 1 had mixed coefficients indicative of shape variations rather than variation in size. This observation is in harmony with findings by Lleonart *et al*., (2000) and Chuhila, (2015) who observed that, any component having all coefficients of the same sign was indicative of size variation whereas any component having both positive and negative coefficients was indicative of shape variation. This observation implies that *Oreochromis niloticus* strains being farmed by aquaculture farmers of Lake Kariba differ in shape. This, too, is a popular opinion shared by Fisheries managers in Zambia (Nasilele, 2020). All O. *niloticus* strains at Yalelo Fishery exhibited negative allometric growth because growth coefficients ranged from a low of 0.757 in strain 2 to a high of 2.5 in strain 1. The coefficient of determination values (Pearson's adjusted r^2) for length-weight relationships were high for all strains at Yalelo Fisherywhich indicated that the length increased with increase in weight of the fish. This was in agreement with previous studies on different fish species from various water bodies (Dalu *et al*., 2013; Ndiaye *et al*., 2015; Saha *et al*., 2019).The determined growth exponent coefficients from length-weight relationshipsare helpful for estimating the weight of a fish of a given length and can be used instudies of gonad development, rate of feeding, metamorphosis, maturity and computing conditionfactors which indicates the wellbeing of fish (Pauly, 1993). Growth exponent coefficients are also used to estimate the weight at age from total catch which is useful in formulation of fish stock assessment models.

Conclusion

Phenotypically, this study delineated *Oreochromis niloticus*fish species of Yalelo Fishery using morphometric measurements.The study revealed thatYalelo Fishery is hosting more than one type of *Oreochromis niloticus*. Application of molecular genetic markers such as microsatellites, cytochrome c oxidase subunit 1 (CO 1) gene and the displacement loop (D-loop) region would be effective methods of examining the discreteness of *Oreochromisniloticus* strains of Yalelo Fishery and facilitate the development of species-specific management strategies.

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